

**PATENT**

Case Docket No. 36856.366

Date: October 20, 2000

BOX PATENT APPLICATION  
 ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application of:

**Inventor(s):** Takao MUKAI, Michio KADOTA and Hideya HORIUCHI**For: SURFACE ACOUSTIC WAVE DEVICE**
☐ Applicant(s) claim(s) benefit under 35 U.S.C. § 119(e) of United States provisional application No. \_\_\_\_\_ filed \_\_\_\_\_
**Enclosed are:**

17 Pages of Specification

3 Sheet(s) of drawings (☐ formal ☒ informal)☒ Declaration and Power of Attorney ☐ Will follow.
☒ Form PTO-1595 and an Assignment of the invention to Murata Manufacturing Co., Ltd. of 26-10 Tenjin 2-chome, Nagaokakyo-shi, Kyoto-fu 617-8555, JAPAN ☐ Will follow

☒ A certified copy of Japanese Patent Appln. No. 11-260936 filed on September 14, 1999, from which priority is claimed in the subject case pursuant to Rule 55b and 35 U.S.C. 119.

☐ A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27.

☒ Information Disclosure Statement, Form PTO 1449, and 2 cited reference(s).

☐ Change of Correspondence Address

☐ Preliminary Amendment

☒ General authorization/request to Petition for Extensions of Time

☒ Return Postcard

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TOTAL CLAIMS	2	-3=	-0-	X 40	\$	OR	X 80	\$-0-
INDEP CLAIMS				X+ 130	\$	OR	+ 260	\$-0-
MULTIPLE DEP CLAIMS PRESENTED				TOTAL =			TOTAL:	\$710.00

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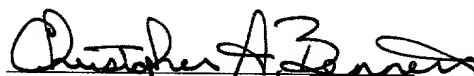
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☐ Any filing fees under CFR 1.16 for presentation or extra claims.

Respectfully submitted,



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## PATENT

Docket No:36856.366

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Takao MUKAI et al.

**For: SURFACE ACOUSTIC WAVE DEVICE**

jc825 U.S. PTO  
09/692668  
10/20/00

## CERTIFICATE OF MAILING

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Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

“EXPRESS MAIL” Mailing Label No.: EL631547155US

Date of Deposit: October 20, 2000

I hereby certify that an application for patent, including:

One-page cover sheet; 17 pages of Specification (which includes 18 claims and a one-page Abstract); 3 Sheets of informal Drawings; an executed Combined Declaration and Power of Attorney; a General Authorization/Request to Petition for Extensions of Time; a check in the amount of \$710.00 to cover the filing fee; an executed Assignment document and Form PTO 1595, along with a check in the amount of \$40.00 to cover the assignment recordation fee; a certified Priority Document; a Transmittal Letter (Form PTO 1082); and Information Disclosure Statement including 2 references; and Return Postcard are being deposited with the U.S. Postal Service “Express Mail Post Office to Addressee” service under 37 C.F.R. § 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Box Patent Application, Washington, D.C. 20231.

Date of Deposit: October 20, 2000

  
Christopher A. Bennett

SURFACE ACOUSTIC WAVE DEVICE

**BACKGROUND OF THE INVENTION**

1. Field of the Invention

The present invention relates to an edge reflection type surface acoustic wave device which utilizes an SH (shear horizontal) type surface acoustic wave.

2. Description of the Related Art

Edge reflection type surface acoustic wave devices which utilize an SH-type surface acoustic wave are well known. The SH-type surface acoustic wave refers to surface acoustic waves such as a BGS (Bleustein-Gulyaev-Shimizu) wave or a Love wave which have a displacement that is perpendicular to the direction of propagation of the surface acoustic wave and include a main component which is parallel to the surface of the substrate. Of these edge reflection type surface acoustic wave devices, in order to suppress bulk waves or to allow for easy production, some have structures in which a step is provided at the edge of the substrate or a groove is provided on the substrate, and the upper portion of the substrate edge or the inside surface of the groove defines the reflection edge, (refer to Japanese Unexamined Patent Application Publication No. 4-82315 and No. 7-263998). In Japanese Unexamined Patent Application No. 4-82315, for example, it is explained that influences of the bulk wave resonance on the SH wave resonance can be prevented and unwanted spurious responses caused by bulk wave resonance can be efficiently

suppressed by providing, at the substrate edge, a step having a greater vertical dimension than the surface of the substrate such that the step is spaced away from the substrate surface resulting in at least 80% of the SH wave energy being concentrated at the step.

However, even if the vertical dimension of the reflection edge is greater than the predetermined value as described above, in some cases, desired resonance characteristics or pass-band characteristics could not be obtained. That is, in a conventional surface acoustic wave device having a reflection edge that is a step or a groove as described above, even if the height of the reflection edge is set to a suitable value, there has been a problem that when the distance between the substrate edge and the reflection edge was larger, ripples occurred in the pass-bands. Moreover, there has been a problem that ripples also occurred as the vertical dimension of the reflection edge became larger.

#### SUMMARY OF THE INVENTION

In order to overcome the problems described above, preferred embodiments of the present invention provide a surface acoustic wave device in which desired resonance characteristics and pass-band characteristics are reliably obtained by reducing the ripples caused by bulk waves.

According to a preferred embodiment of the present invention, a surface acoustic wave device includes a piezoelectric substrate having a pair of substrate edges and an upper surface therebetween. The piezoelectric substrate has at least one inner edge arranged to contact the main region and extending from the upper surface toward a bottom surface of the piezoelectric substrate inside one of the substrate



shown in the drawings several forms which are presently preferred, it being understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a perspective view of a surface acoustic wave device according to a first preferred embodiment of the present invention.

Fig. 2 is a sectional view of the surface acoustic wave device according to the first preferred embodiment of the present invention.

Fig. 3 is a sectional view of a surface acoustic wave device according to a second preferred embodiment of the present invention.

Fig. 4 is a graph showing the relationship between the distance between a substrate edge and a reflection edge, and the amount of variation of in-band GDT deviation.

Fig. 5 is a graph showing the relationship between the height of the reflection end-surface and the in-band characteristics (GDT deviation, minimum insertion loss).

Fig. 6 is a block diagram of a communication device according to a third preferred embodiment of the present invention.

#### **DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

As will be clear from the results of an experiment described later, the inventors of the present invention have discovered that ripples in the pass-band can be minimized by providing a reflection edge inside of the substrate edge such that the distance between the reflection edge and the

corresponding substrate edge is set at a predetermined amount or less and a height of the reflection edge is set at a value in a predetermined range. Thus, it is possible to obtain the desired excellent resonance characteristics and pass-band characteristics.

If the distance between the substrate edge and the reflection edge is not suitable, the bulk waves reflected at the substrate edge strongly affect the pass-band characteristics, and if the height of the reflection edge is more than a certain value, the bulk waves are also reflected by the reflection end-surface and these reflected bulk waves strongly affect the pass-band characteristics.

The surface acoustic wave device according to preferred embodiments of the present invention include devices in general which utilize an SH-type surface acoustic wave such as a surface acoustic wave resonator, a longitudinally coupled resonator filter, a transversely coupled resonator filter, a ladder type filter or other suitable devices. These devices include at least one interdigital transducer (IDT) on a piezoelectric substrate, and a reflection edge for reflecting the surface acoustic wave is located at least one side of the IDT.

Furthermore, a communication device according to one preferred embodiment of the present invention includes at least one of the surface acoustic wave devices according to other preferred embodiments of the present invention. Thereby, a communication device with excellent characteristics can be obtained.

Referring to Fig. 1 and 2, a surface acoustic wave device according to a first preferred embodiment of the present invention is explained. Although the widths of electrode

fingers are illustrated as being wide in the following figures, the electrode fingers of an actual device preferably have very fine widths.

The surface acoustic wave device according to this preferred embodiment is an edge reflection type longitudinally coupled resonator filter, and is provided with a substantially rectangular planar piezoelectric substrate 2. The piezoelectric substrate 2 preferably includes, for example, piezoelectric ceramics such as lead titanate zirconate ceramics or piezoelectric single crystals such as  $\text{LiNbO}_3$  and  $\text{LiTaO}_3$ . The piezoelectric substrate 2 has substrate edges 21 and 22 which are opposed to each other, and grooves 23 and 24 arranged substantially parallel to the corresponding substrate edges 21 and 22 and extending from the upper surface toward the bottom surface are disposed on the upper surface (one main surface) inside of both of the edges 21 and 22. Inside surfaces 23a and 24a of the grooves 23 and 24 are in contact with of a main region of the upper surface and become new inner edges for the main region. As will be explained next, SH type surface acoustic waves are excited on the main region, and therefore, the inside surface 23a and 24a function as reflection edges 23a and 24a.

Two IDTs 3 and 4 are disposed between the grooves 23 and 24 on the upper surface of the piezoelectric substrate 2. The IDT 3 preferably includes a pair of comb-shaped electrodes 3a and 3b, the comb-shaped electrodes 3a and 3b each have a plurality of electrode fingers, and the electrode fingers of the comb-shaped electrodes 3a and 3b are arranged so as to be interleaved with each other. Similarly, the IDT 4 preferably includes a pair of comb-shaped electrodes 4a and 4b, the comb-shaped electrodes 4a and 4b being constituted in the same





2 $\lambda$  to about 6 $\lambda$ .

Next, the constitution of the surface acoustic wave device according to a second preferred embodiment of the present invention is shown in Fig. 3. In the surface acoustic wave device of this preferred embodiment, a step is provided on the substrate edges to define the reflection edges. That is, in this surface acoustic wave device, steps 25 and 26 are respectively provided on two opposing edges 21 and 22 of a piezoelectric substrate 2. The steps 25 and 26 are arranged so as to cut the upper surface of the piezoelectric substrate 2 to form a substantially rectangular shape, with edges 21a and 22a above the steps 25 and 26 defining opposing edges as reflection edges. The elements other than those constituting the reflection edges 21a and 22a are the same as the constitution of the first preferred embodiment, and thus an explanation thereof is omitted.

In this surface acoustic wave device, the distances between the reflection edges 21a and 22a and the substrate edges 21 and 22 are respectively about 8 $\lambda$  or less, and the heights of the reflection edges 21a and 22a, i.e. the distances H of the steps 25 and 26 from the top surface of the piezoelectric substrate 2, are within the range of about 2 $\lambda$  to about 6 $\lambda$ .

The surface acoustic wave devices of the first and second preferred embodiments are preferably manufactured by the following manner. First, many IDTs constituting the surface acoustic wave devices are formed on a piezoelectric substrate. Next, grooves (23 and 24 in Fig. 1 and 2) for forming reflection edges are formed on the top surface of the piezoelectric plate by using a dicer or other suitable cutting device or method. The grooves are precisely formed so that



were evaluated with the GDT deviation.

Fig. 4 shows the relationship between the distance  $L$  and the amount of variation of the GDT deviation in the pass-band after the piezoelectric substrate was cut, using the piezoelectric substrate before being cut as a reference criterion, in the surface acoustic wave device of the first and second preferred embodiments. This is a 1st IF filter for a mobile phone with a center frequency of 190 MHz and a pass-band width of 5 MHz, constituted by 34 pairs of electrode fingers on the IDTs 3 and 4, a wavelength  $\lambda$  of 20  $\mu\text{m}$  and a height of the reflection edge of  $3\lambda$ . As shown in Fig. 4, in-band GDT deviation drastically varies when the distance  $L$  between the substrate edge and the reflection edge exceeds about  $8\lambda$ , the variation amount of GDT deviation is small when the distance  $L$  is about  $8\lambda$  or lower, and the amount of variation of the GDT deviation is large when the distance  $L$  exceeds about  $8\lambda$ . That is, setting the distance  $L$  to less than about  $8\lambda$  can reduce the ripples in the pass-band.

Furthermore, the steps are constructed to prevent chipping or other defects on the reflection edges, so as to form reflection edges with high accuracy. Preferably, the distance  $L$  is about  $\lambda/10$  or more.

Fig. 5 shows the relationship between the height  $H$  of the reflection edge and in-band GDT deviation and minimum insertion loss in the surface acoustic wave device according to various preferred embodiments of the present invention. The data is for when the distance  $L$  between the substrate edge and the reflection edge is set to  $\lambda$ . As shown in Fig. 5, in-band GDT deviation becomes lower within the range of a height  $H$  of the reflection edge by about  $2\lambda$  to about  $6\lambda$ , this is a

practical level of about  $0.125 \mu\text{s}$  or lower. If the height  $H$  of the reflection edge is lower than about  $2\lambda$ , it cannot reflect the surface acoustic wave energy, and the minimum insertion loss becomes high. That is, if the height  $H$  of the reflection edge is set within the range of about  $2\lambda$  to about  $6\lambda$ , ripples in the pass-band and insertion loss are minimized to obtain excellent pass-band characteristics. Moreover, as can be understood from Fig. 5, when the height  $H$  of the reflection edge is set within the range of about  $2\lambda$  to about  $4\lambda$ , the in-band GDT deviation becomes  $0.10\mu\text{s}$  or less, thereby obtaining greatly improved pass-band characteristics.

Although the preferred embodiments are explained by using an example of the structure of a longitudinally coupled resonator filter that includes a pair of reflection edges, it is not limited to a constitution having the edges on both sides of the IDTs. Alternatively, a device having the reflection edge on one side of the IDT constituting the surface acoustic wave device and the reflector on the other side may be used. For example, when a plurality of surface acoustic wave resonators are arranged on the same piezoelectric substrate to constitute a ladder type filter, a constitution utilizing edge reflections of a reflection edge and reflections of a reflector is preferably used.

Next, Fig. 6 shows the structure of a communication device according to a third preferred embodiment of the present invention. This communication device is constructed by connecting an antenna ANT to an antenna terminal of a duplexer DPX comprising a transmission filter TX and a reception filter RX, connecting a transmission circuit to an input terminal of the transmission filter TX, and connecting a reception circuit to an output terminal of the reception filter RX. Transmission

signals from the transmission circuit are transmitted from the antenna ANT through the transmission filter TX. Further, received signals received by the antenna ANT are inputted to the reception circuit through the reception filter RX.

Here, the surface acoustic wave device according to the present preferred embodiment of the present invention can function as the reception filter RX, the 1st IF filter of the reception circuit, and various kinds of interstage filters of a communication device or resonance element. By using the surface acoustic wave device according to various preferred embodiments of the present invention, a communication device having excellent characteristics can be obtained.

While preferred embodiments of the invention have been described above, various modes of carrying out the principles disclosed herein are contemplated as being within the scope of the following claims. Therefore, it is understood that the scope of the invention is not to be limited except as otherwise set forth in the claims.

What is claimed is:

1. A surface acoustic wave device comprising:

a piezoelectric substrate having a pair of substrate edges and an upper surface therebetween and including a main region and a bottom surface, the piezoelectric substrate having at least one inner edge arranged to contact the main region and to extend from the upper surface toward the bottom surface of the piezoelectric substrate inside one of the substrate edges;

an interdigital transducer provided on the main region of the piezoelectric substrate such that a shear horizontal type surface acoustic wave excited by the interdigital transducer and having a wavelength of  $\lambda$  are reflected by the at least one inner edge;

wherein a distance L between the at least one inner edge and the corresponding one of the substrate edges is substantially equal to about  $8\lambda$  or less.

2. A surface acoustic wave device according to claim 1, wherein the at least one inner edge has a height H in the range of about  $2\lambda$  to about  $6\lambda$ .

3. A surface acoustic wave device according to claim 1, wherein the surface acoustic wave device comprises one of a surface acoustic wave resonator, a longitudinally coupled resonator filter, a transversely coupled resonator filter, and a ladder type filter.

4. A surface acoustic wave device according to claim 1, wherein the piezoelectric substrate is made of at least one of piezoelectric ceramics and piezoelectric single crystals.

5. A surface acoustic wave device according to claim 1, wherein the upper surface of the piezoelectric substrate has a pair of grooves arranged substantially parallel to the substrate edges and extending from the upper surface toward the bottom surface.

6. A surface acoustic wave device according to claim 5, wherein the pair of grooves have inside surfaces arranged to contact the main region of the upper surface and defining inner edges for the main region.

7. A surface acoustic wave device according to claim 1, wherein the inside surfaces define reflection edges for reflecting the shear horizontal type surface acoustic wave.

8. A surface acoustic wave device according to claim 5, wherein at least two IDTs are disposed between the grooves on the upper surface of the piezoelectric substrate.

9. A surface acoustic wave device according to claim 8, wherein the at least two IDTs include a plurality of electrode fingers, and if the wavelength of the surface acoustic wave is represented by  $\lambda$ , the widths of the outermost electrode fingers of the at least two IDTs are approximately  $\lambda/8$  and the widths of all of the other electrode fingers are approximately  $\lambda/4$ .

10. A communication device comprising:  
at least one surface acoustic wave device including:  
a piezoelectric substrate having a pair of  
substrate edges and an upper surface therebetween and



including a main region and a bottom surface, the piezoelectric substrate having at least one inner edge arranged to contact the main region and to extend from the upper surface toward the bottom surface of the piezoelectric substrate inside one of the substrate edges;

an interdigital transducer provided on the main region of the piezoelectric substrate such that a shear horizontal type surface acoustic wave excited by the interdigital transducer and having a wavelength of  $\lambda$  are reflected by the at least one inner edge;

wherein a distance L between the at least one inner edge and the corresponding one of the substrate edges is substantially equal to about  $8\lambda$  or less.

11. A communication device according to claim 10, wherein the at least one inner edge has a height H in the range of about  $2\lambda$  to about  $6\lambda$ .

12. A communication device according to claim 10, wherein the surface acoustic wave device comprises one of a surface acoustic wave resonator, a longitudinally coupled resonator filter, a transversely coupled resonator filter, and a ladder type filter.

13. A communication device according to claim 10, wherein the piezoelectric substrate is made of at least one of piezoelectric ceramics and piezoelectric single crystals.

14. A communication device according to claim 10, wherein the upper surface of the piezoelectric substrate has a

pair of grooves arranged substantially parallel to the substrate edges and extending from the upper surface toward the bottom surface.

15. A communication device according to claim 14, wherein the pair of grooves have inside surfaces arranged to contact the main region of the upper surface and defining inner edges for the main region.

16. A communication device according to claim 15, wherein the inside surfaces define reflection edges for reflecting the shear horizontal type surface acoustic wave.

17. A communication device according to claim 14, wherein at least two IDTs are disposed between the grooves on the upper surface of the piezoelectric substrate.

18. A communication device according to claim 17, wherein the at least two IDTs include a plurality of electrode fingers, and if the wavelength of the surface acoustic wave is represented by  $\lambda$ , the widths of the outermost electrode fingers of the at least two IDTs are approximately  $\lambda/8$  and the widths of all of the other electrode fingers are approximately  $\lambda/4$ .

#### ABSTRACT OF THE DISCLOSURE

A surface acoustic wave device includes a piezoelectric substrate having a pair of substrate edges and an upper surface therebetween. The piezoelectric substrate has at least one inner edge which is in contact with a main region and extends from the upper surface toward a bottom surface of the piezoelectric substrate inside one of the substrate edges. An interdigital transducer is provided on the main region of the piezoelectric substrate such that a SH type surface acoustic wave excited by the interdigital transducer and having a wavelength of  $\lambda$  is reflected by the at least one inner edge. A distance L between the at least one inner edge and the corresponding one of the substrate edges is substantially equal to about  $8\lambda$  or less.

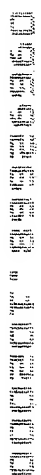
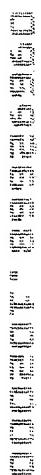
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FIG. 3

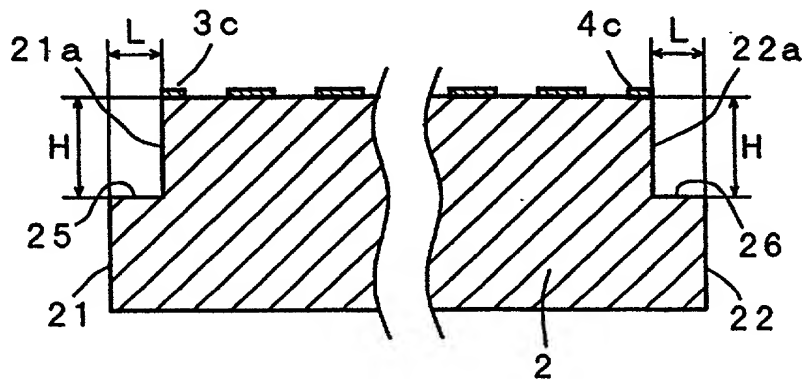


FIG. 4

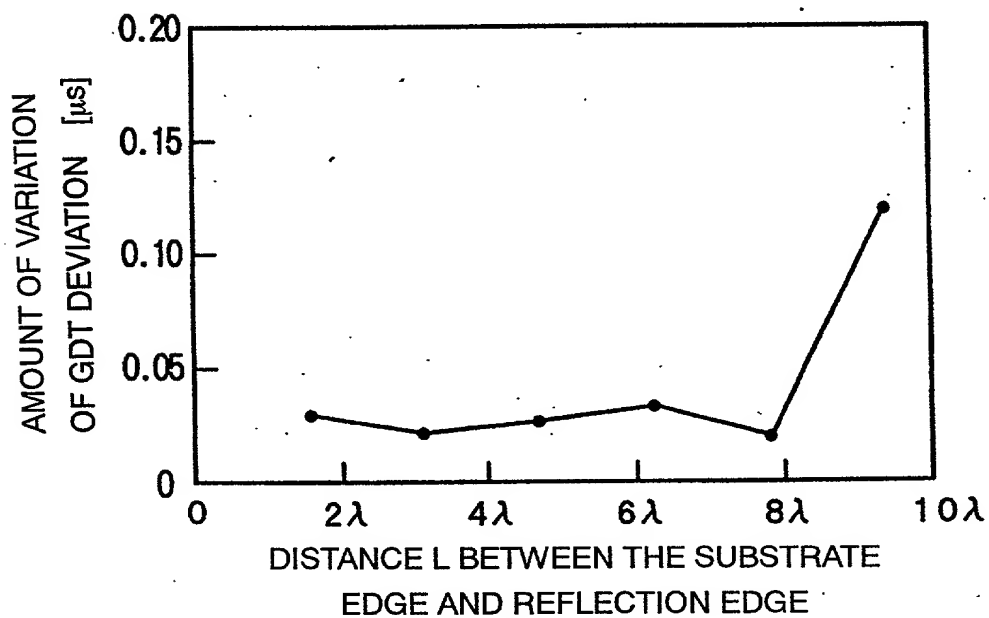


FIG. 5

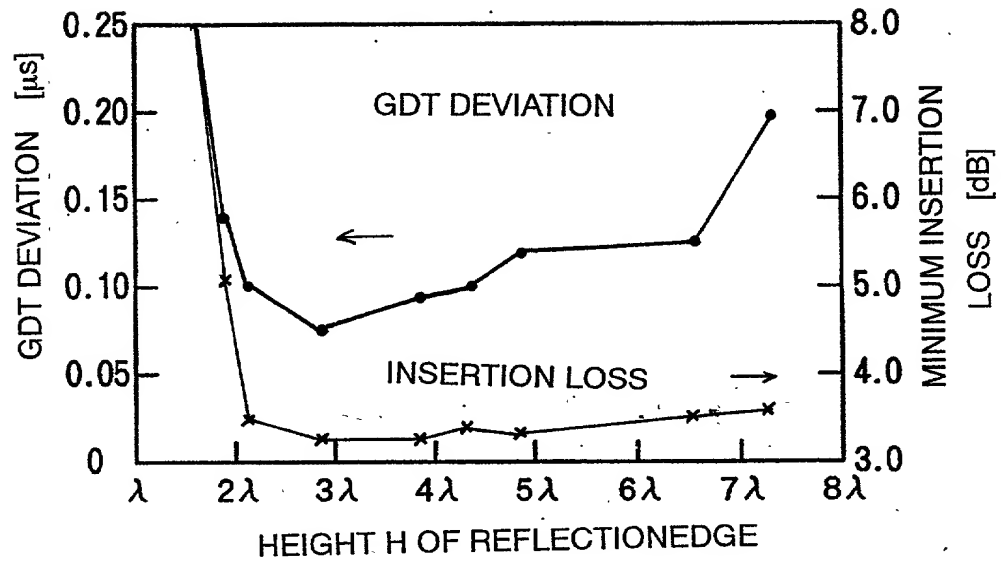
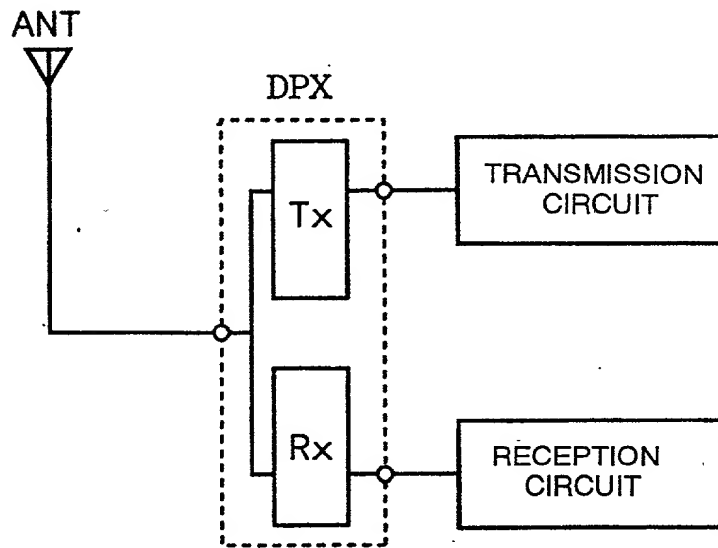


FIG. 6



Attorney Docket No. 36856.366

## DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **SURFACE ACOUSTIC WAVE DEVICE** the specification of which is attached hereto unless the following box is checked:

☐ was filed on \_\_\_\_\_ as United States Application Number or PCT International Application Number \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)	Priority Date	Priority Claimed
<u>11-298577</u> (Number)	<u>JAPAN</u> (Country) (PCT)	<u>October 20, 1999</u> (Day/Month/Year Filed)
		Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

_____ (Application Number)	_____ (Filing Date)
_____ (Application Number)	_____ (Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

_____ (Application Number)	_____ (Filing Date)	_____ (Status – patented, pending, abandoned)
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(Application Number)

(Filing Date)

(Status - patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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Fairfax, VA 22030  
(703) 385-5200

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first inventor (given name, family name) Takao MUKAI

Inventor's signature Takao Mukai Date October 2, 2000

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Inventor's signature Michio Kadota Date October 2, 2000

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